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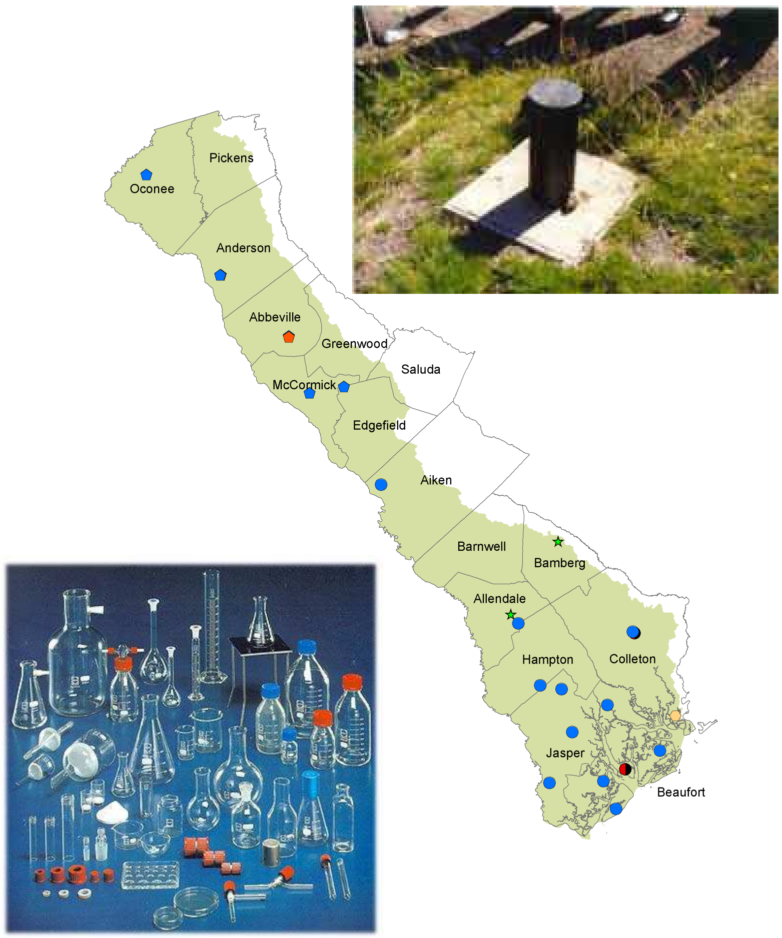
South Carolina Department of Health and Environmental Control

South Carolina Ambient Groundwater Quality Monitoring Network Annual Report, 2005



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South Carolina Ambient Groundwater Quality Report, 2005 Summary

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Technical Report Number: 012-06

Bureau of Water
November 2006

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Ambient Groundwater Monitoring Network

Abstract

An ambient groundwater quality monitoring network has been established in South Carolina for the purpose of obtaining statewide and aquifer-specific baseline values of groundwater quality. This network utilizes selected public and private water supply wells for obtaining groundwater samples. Initial sampling was performed in 1987 encompassing 19 wells in four counties. As of 2005, wells from additional counties have been added to the network from all the major aquifers of South Carolina, to form a comprehensive network of 116 active wells sampling various depths and locations of the state's major aquifers. The geology of South Carolina influences the quality and composition of the groundwater and dictates the methods of obtaining groundwater. The Fall Line separates the Piedmont geologic units, located in the northwest portion of the state, from the Coastal Plain geologic units, located in the southeast portion of the state. Wells sampled in the Piedmont tap either the thin layer of saprolite at the surface, or the underlying fractured bedrock, consisting of low to medium grade metamorphic rocks with scattered granitic plutons. Wells sampled to the east of the fall line tap one of the several extensive Coastal Plain aquifers that generally consist of sand, silt or permeable carbonate rocks.

Introduction

The state of South Carolina depends upon its groundwater resources to supply an estimated 40 percent of its residents. To monitor the ambient quality of this valuable resource, a network of existing public and private water supply wells has been established which provide groundwater quality data representing all of the State's major aquifers.

Although a great deal of groundwater quality monitoring is presently being carried out within South Carolina, most of this monitoring is generally being conducted at regulated industrial or commercial sites which have known or potential groundwater contamination. In general, these sites are monitored for water quality only in the uppermost (water table) aquifer. The monitoring program described herein has been designed to avoid wells in these areas of known or potential contamination, thereby allowing for the assumption that variability in water chemistry reflects differences in any aquifer's background geochemistry caused by the natural heterogeneity of geologic materials and not man-made causes for changes in aquifer chemistry.

Data derived from this monitoring network has been analyzed for the purpose of identifying variations in water chemistry among the State's major aquifers and developing an understanding of the ambient groundwater quality across South Carolina. The concentrations of certain chemical parameters in a region and/or aquifer may be used as a general indicator against which conditions of potential contamination can be assessed at sites within that area. It is not, however, intended to be used for all site specific comparisons of water quality.

This report is presented in two sections. The first section is an outline of the methods involved in establishing and operating the monitoring network. This includes details concerning well selection, sample collection, chemical analysis, data management, data analysis, and implementation schedules. The second section is a report of the results of the monitoring efforts in the Savannah-Salkehatchie Basin. Results include a discussion of the geology and hydrogeology of the aquifers monitored, and in addition, a discussion of aquifer specific and geographic variations in water quality.

Objectives

The primary objective of the monitoring network is to develop a baseline for ambient groundwater quality for South Carolina's groundwater resources. Through utilization of this data many other objectives may be achieved. Included among these secondary objectives are:

1) To determine areal variations in regional groundwater quality.
2) To determine aquifer-specific variability in water quality.
3) To detect any significant changes in groundwater quality over time. These time related variations are capable of being determined on both a regional and a statewide level.
4) To supply background, ambient groundwater quality data for certain areas or aquifers where possible future contamination investigations may occur.

Methods and Organization

Well Selection

The ambient monitoring network is comprised exclusively of existing public and private water supply wells. Public wells are generally preferred and constitute a majority of the network. Preference is given to public supply wells because of their potential for greater longevity and continuity of ownership in comparison to privately owned water sources.

Initial well selection steps are governed by the availability and completeness of drilling records contained within state files. If complete records exist with respect to location, depth, aquifer, etc., a well may then be further considered for incorporation into the monitoring network. Although past water quality analysis data exist for many network wells, particularly public supply wells, no consideration is given to these data when selecting network wells. This avoidance is necessary to avoid creating a bias in water quality toward chemical constituent concentrations that are higher or lower than anticipated.

In order to sample water from "all" portions of the State's major aquifers, well selection criteria also include consideration of which aquifer each well is utilizing, along with the geographic distribution of wells within each aquifer. A final consideration that is addressed when selecting network wells is the presence of, or potential for, contamination within the area. At the time of well sampling, a field check of the area surrounding the well site is performed. If a significant potential contamination source is located in the vicinity, the well is not included in the monitoring network.

Sample Collection and Chemical Analysis

Proper sampling protocol is essential for any monitoring program that is to provide meaningful and accurate data. Nacht (1983) provides a thorough review of monitoring sampling considerations, many of which may be directly applied to an ambient monitoring program. The Department of Health and Environmental Control, Environmental Quality Control (ECQ) Standard Operating Procedures and Quality Assurance Manual, EQC SOP and QA Manual for short, provides a thorough review of monitoring sampling considerations, many of which may be directly applied to an ambient monitoring program. The EQC SOP and QA Manual includes Sections 5 and 6, "Groundwater Monitoring and Sampling", and "Sampling of Public and Private Water Supplies", respectively, that specifically outline sample collection and preservation procedures. A brief outline of some of the practices and considerations is presented below.

Sampling must be performed in a manner that will allow collection of groundwater that has not been chemically altered by the well system. Public supply wells can normally be sampled from a blow-off pipe or sample cock that is situated between the wellhead and any treatment systems. Private well samples are ideally drawn from the tap closest to the well. Water should be allowed to flow for a time period that is sufficient to recycle water through the entire volume of any pressure tanks in the system if the sample is collected past a pressure tank. Unless a significant volume of water has been pumped from a well immediately prior to sampling, an amount of water equal to or greater than the well volume should also be flushed through the system in order to reduce the likelihood of chemical alteration from well casings, pumps, or residence time in a well.

Samples are collected in appropriately prepared laboratory bottles that are compatible with the chemical constituent being measured. All samples are preserved with proper chemicals [such as sulfuric acid for total organic carbon (TOC), and nitric acid for metals] and refrigerated until submitted to the laboratory for analysis. Proper chain-of-custody protocols and holding times are followed to further ensure the quality and reproducibility of sample results.

Laboratory analyses of water samples cover a wide spectrum of parameters that, as a whole, provide the information that is required to characterize aquifer-specific groundwater quality. Appendix A presents a list of the chemical parameters that were analyzed. The sampling frequency for all network wells is once every five years.

Any well samples that have chemical concentrations in excess of the National Primary Drinking Water Regulations (Appendix B) will be re-sampled and analyzed to confirm constituent concentrations. If it is determined that a well is contaminated by man-made causes, the well will be removed from the ambient monitoring network, and the well owner will be referred to proper South Carolina Department of Health and Environmental Control (SCDHEC) personnel for assistance. Future sampling of any wells found to be contaminated will be performed as part of a contamination source investigation.

Data Management and Analysis

The ease with which information can be accessed is a critical factor in determining the success of any monitoring program. In the ambient monitoring network described here, all data related to well information and water quality are stored in an Access database and in STORET, the US Environmental Protection Agency's STOrage and RETrieval system for water quality data. Analyses of network groundwater samples may be presented by way of trilinear (Piper) diagrams, Stiff Diagrams, and graphs. Discussion of various data analyses consider comparisons of water quality to factors such as geology of aquifers, variations of chemical constituent levels among regions, and changes in water quality over time. Tabular water quality data is presented as table 1, and a general overview of the physical properties and some common parameters are shown in figure 8.

Implementation Schedule

The ambient monitoring network was initiated in 1987 on a trial basis in a four county area. At that time, the network included 19 wells, both public and private, and was primarily intended to test and establish the network's methods. In 1988 and 1989, ten and sixteen additional counties were added, respectively. Nineteen wells were added to the network in 1990, another nine wells were added in 1991, and one more in 2000 and 2001. Each year a selection of the wells from a specific aquifer were sampled on a five-year cycle, until 2000. The current strategy involves sampling all represented aquifers within one of the eight major watersheds (fig. 1). These watershed-wide sampling events and their scheduled sampling dates are as follows:

2003: **Pee Dee** (28 wells): Piedmont Bedrock, Middendorf, Tertiary Sands, Black Creek, Surficial Sands

2004: **Broad** (10 wells): Piedmont Bedrock and Saprolite

2005: **Savannah and Salkehatchie** (25 wells): Piedmont Bedrock, Saprolite, Middendorf, Pee Dee/Black Creek, Tertiary Limestone

2006: **Saluda and Edisto** (29 wells): Piedmont Bedrock, Saprolite; Middendorf, Black Mingo, Tertiary Limestone

2007: **Catawba and Santee** (15 wells): Piedmont Bedrock, Middendorf, Black Creek, Black Mingo

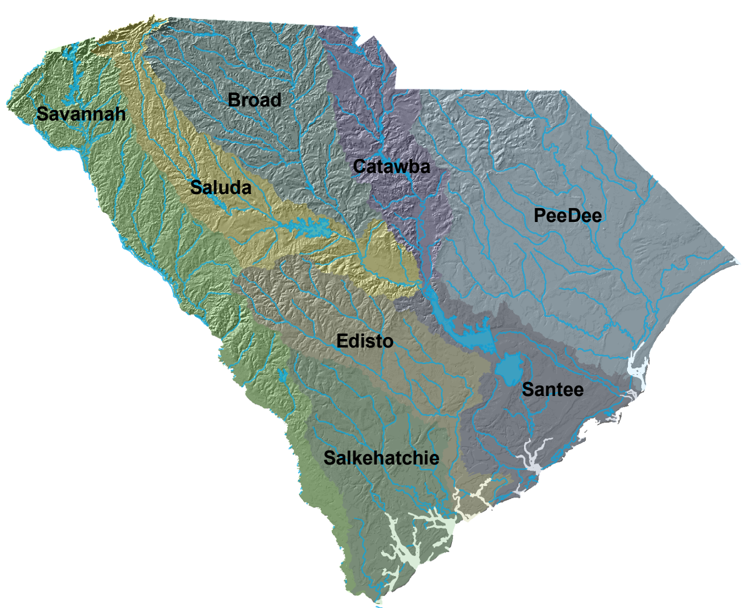

Figure 1: Locations of the major watersheds of South Carolina. This report highlights groundwater sampling conducted in the Savannah and Salkehatchie Basins.

2005 Monitoring Program

Location

The 2005 ambient groundwater quality monitoring consisted of sampling twenty-four (24) wells in twelve (12) counties within the Savannah-Salkehatchie Basin (fig. 2). Two (2) wells were sampled from the Blue Ridge Region, six (6) wells were sampled from the Piedmont, and sixteen (16) were sampled from the Coastal Plain. Three wells utilized in previous years for monitoring were either abandoned, destroyed, or were built-over by urban development and were unavailable for sampling.

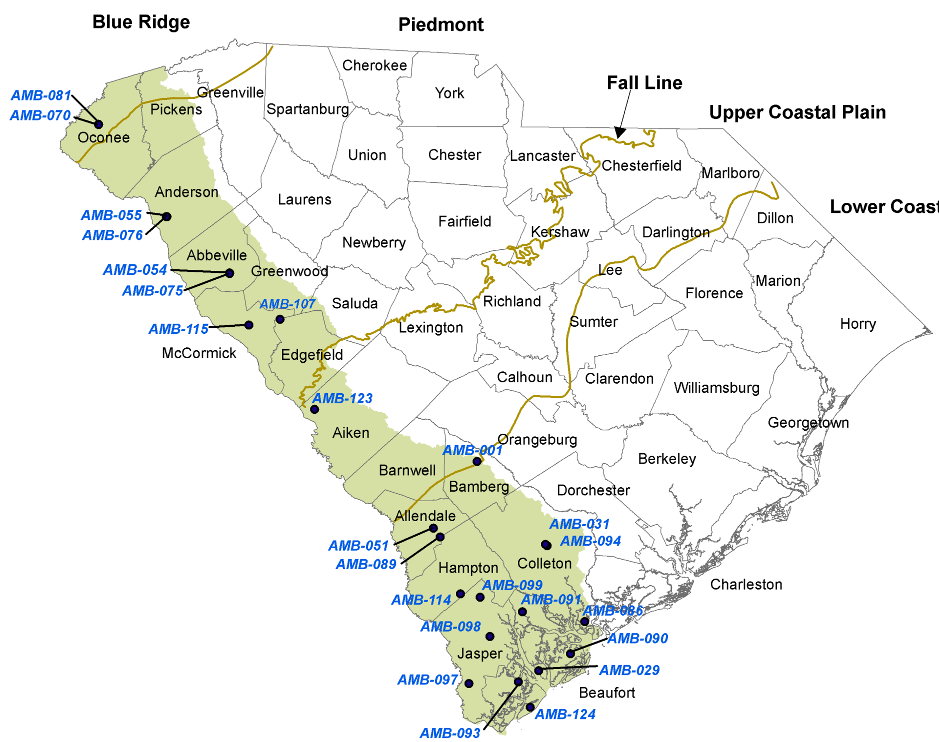

Figure 2: Locations of wells within the Savannah-Salkehatchie Basin sampled during 2005

Hydrogeology, and Groundwater Quality of the Savannah-Salkehatchie Basin

Geology and Geography Overview

The Savannah-Salkehatchie Basin represents one of the most geologically and geographically diverse watersheds in South Carolina. The basin bounds the diverse physiographic regions of the Blue Ridge Mountains, the Piedmont, and the Atlantic Coastal Plain. The watershed is divided roughly in half by the Fall Line (fig. 2), a distinct surface transition from the igneous and metamorphic rocks of the Piedmont and Blue Ridge to the sedimentary formations of the Coastal Plain. This transition also marks the boundary between two distinct hydrogeologic provinces: the collective aquifer systems of the Blue Ridge and Piedmont Province, and the aquifers of the South Atlantic Coastal Plain Province.

The Piedmont region of the Savannah-Salkehatchie Basin is a plateau of forested rolling hills with tight, dissected river valleys that generally contain small flood plains. Elevations within the basin range from approximately 3000 feet to sea level. The watershed lies between the Saluda and Edisto Basins to the northeast, and Georgia's portion of the Savannah Basin to the west. Streams generally follow a dendritic pattern and drain the mountain and foothills portion of the Savannah-Salkehatchie and eventually discharge to the Atlantic Ocean via larger rivers in the Coastal Plain. Although some densely populated areas exist within the basin, many areas are only lightly populated, with many small towns and rural agricultural areas.

The majority of rocks in the Blue Ridge and Piedmont Provinces are medium-to-high grade metamorphic rocks such as schist, gneiss, and amphibolite. These rocks are generally stratified and compositionally layered with distinct foliation. In addition, lineaments and fault systems are common in the region, and several major thrust sheets are present in the basin. Numerous granitic plutons and stocks have intruded older metamorphic rocks, and are often marked by areas of higher topography; a result of the massive, resistant nature of these intrusive rocks.

Because of the warm, humid conditions, the crystalline rocks are heavily weathered, and a mantle of the clayey residuum, saprolite, overlies most of the bedrock in the region. As a result of weathering processes, iron oxide-stained kaolinite and other aluminosilicate clay minerals are the dominant constituents of upland soils in many areas. Modern fluvial sediments generally occupy only the active bed and small floodplains of local streams and rivers.

The sedimentary deposits that contain the various Coastal Plain aquifers are the result of various sea level fluctuations and concomitant differential sedimentation and erosion. Beginning at the Fall Line, a featheredge of thin sediments tapers to a thick (3000+feet) sequence of alternating sands, limestones, and clays that contain many individual aquifer units (fig. 3).

The individual sedimentary units that comprise the aquifers and confining units are generally thin in the upper Coastal Plain, and consequently, in some areas the entire sedimentary package may act as a single aquifer. Geologists have assigned the name Floridan-Midville aquifer to the saturated sediments in the upper Coastal Plain to reflect the lack of confinement between individual aquifer units. Farther downdip in the middle Coastal Plain, the aquifers become more distinct where confining bed sediments are ticker and more extensive. Several of the wells sampled in the Savannah-Salkehatchie basin are in the upper Coastal Plain. These wells have been assigned to a recognized aquifer, however the water chemistry may be influenced by the poorly confined units above and below.

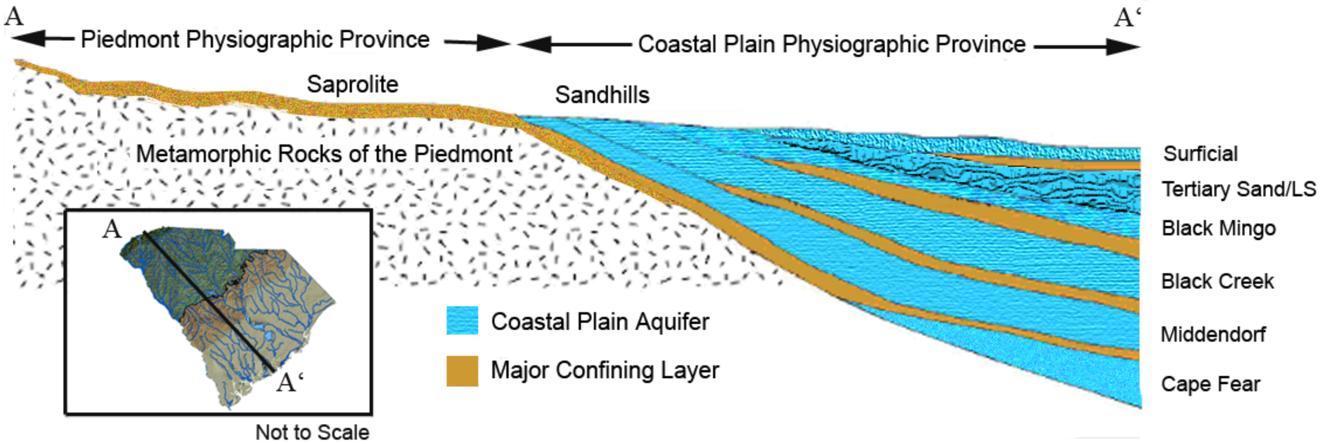

Figure 3: Generalized hydrogeologic cross-section from the Blue Ridge through the Lower Coastal Plain in South Carolina

Crystalline Bedrock Aquifer/Saprolite

Groundwater supplies in the Piedmont and Blue Ridge physiographic provinces of South Carolina occur in three types of hydrogeologic environments. These include the unweathered fractured crystalline rocks, the overlying saprolite, and to a limited extent, alluvial valley-fill deposits. Most public supply wells are completed in fractured crystalline igneous and metamorphic rocks, often referred to as "bedrock", while some private wells are simply bored into the overlying saprolite. Although the bedrock exists in a variety of mineralogical assemblages and textures, it has not been hydraulically characterized to an extent that allows designation of separate or distinct aquifers, although some sections of bedrock clearly display greater water-yielding properties than others across South Carolina (Oldham, 1986). For the purposes of this report, all groundwater occurring in the metamorphic and igneous rocks of the Piedmont and Blue Ridge provinces is referred to as either the Piedmont Bedrock aquifer, or the Crystalline Bedrock aquifer.

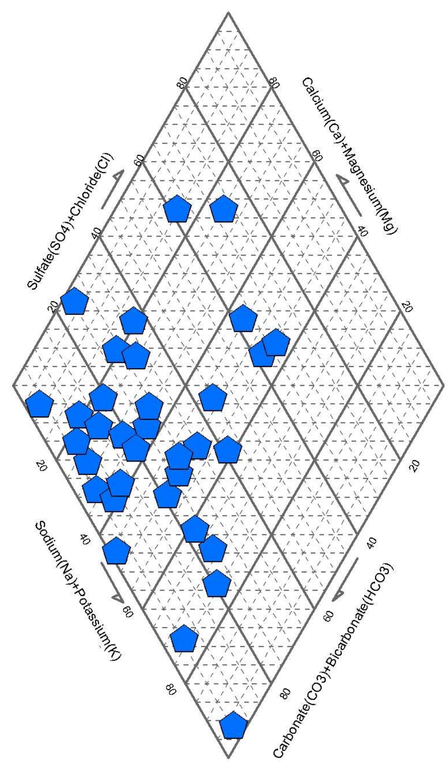

Figure 4: Partial ternary diagram of samples results from the Crystalline Bedrock aquifer in South Carolina.

Yields from crystalline bedrock vary greatly among wells, depending primarily upon the existence of joints, foliation, and fractures within the rock. Well performance further depends upon the size of fractures and degree of fracture interconnection. Fractures generally occur as the result of stress imposed on the rock mass, and can be found in many different orientations, from vertical to horizontal joint sets. Large fractures, on the order of several inches, can be surprisingly common in some areas, while other locations display tight, poorly connected joints where the rocks are more massive, as in the case of granite or strongly recrystallized metamorphic rocks.

The overlying saprolite and the transition zone between saprolite and the unaltered bedrock is hydraulically connected with the underlying crystalline rocks and provides the primary source of recharge water to Crystalline Bedrock aquifer system. Some investigators have reported a positive correlation between the thickness of saprolite and soils overlying bedrock to bedrock well yields (Mitchell, 1995). Yields of 4 to 170 gallons per minute (gpm) from the 30 network wells in the Piedmont bedrock have been recorded.

The chemistry of groundwater samples is affected by several factors, including the lithology of the bedrock, residence time of the groundwater, and influences by manmade sources of alteration/contamination. Because the lithology of the bedrock differs greatly within the Piedmont, so too does the composition of groundwater. Results of laboratory analyses of samples obtained within the Savannah-Salkehatchie Basin are presented in tabular form in Table 1, and indicate that calcium and sodium (in that order) are the dominant cations. Generally speaking, groundwater from the Piedmont is usually a calcium carbonate-type water (fig. 4), though significant variation exists.

Analyses indicate that the water samples from 2005 ambient monitoring display great similarity in composition, and are suitable for most purposes, with minor exceptions. Ambient wells AMB-081, AMB-070, and AMB-076 displayed levels of beryllium in excess of the Maximum Contaminant Level (0.004 ppm). Beryllium is a metal that occurs naturally in igneous and metamorphic rocks, and in precious stones such as emerald and aquamarine. Consumption of groundwater in excess of the MCL for extended periods of time may lead to intestinal damage. Lifetime exposure at levels above the MCL may lead to bone damage or cancer. In addition to beryllium, wells AMB-081 and AMB-070 exceed the Secondary Standard for manganese (0.05 ppm), and may cause staining of pluming fixtures if used for domestic supply. Based on the total dissolved solids (TDS), sodium, calcium and magnesium concentrations, the water is suitable for most irrigation purposes and has a low-to-medium salinity hazard.

Some of the sampling sites in the Savannah-Salkehatchie Basin consist of "paired" wells, where one well is completed in the saprolite one in the fractured crystalline bedrock. The wells are considered pairs due to their proximity, and are used for comparing water chemistry between the saturated saprolite and the underlying bedrock system.

Based upon analysis of chemical data from the entire network's saprolite/bedrock well pairs indicate a similarity in composition. Minor differences in the concentration of dissolved silica and metals such as calcium, iron and sodium are generally the only exception. Most of the bedrock wells displayed higher concentrations of silica, while the saprolite wells displayed higher concentrations of iron. Figure 5 illustrates the composition of 2005 ambient samples with respect to some common cations for well pairs located in the Savannah-Salkehatchie basin.

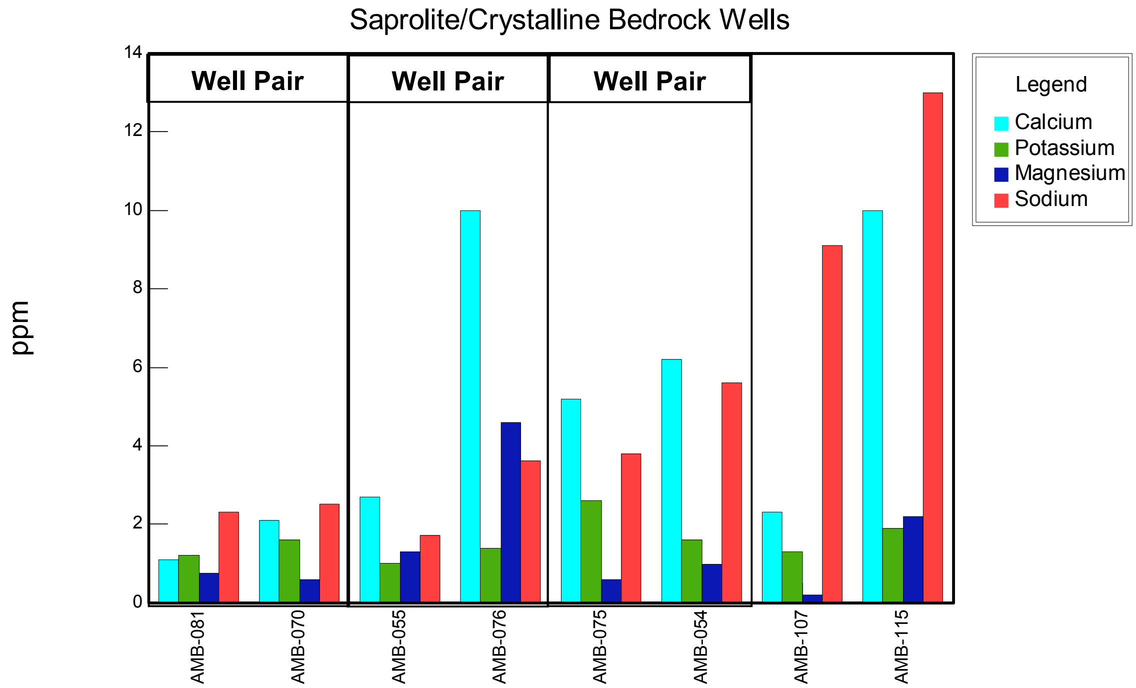

Figure 5: Comparison of selected water quality results from bedrock/saprolite wells pairs within the Savannah-Salkehatchie Basin

Middendorf Aquifer

The Middendorf Aquifer overlies the crystalline bedrock and associated saprolite and stretches from the upper Coastal Plain beyond the Atlantic coastline where it is buried by younger Coastal Plain sediments at maximum depths of over 3000 feet (fig.3). In the upper Coastal Plain, the Middendorf Aquifer provides groundwater to numerous domestic, municipal, and industrial users; however, it is tapped by only a few wells in the middle and lower Coastal Plain regions. The lower usage toward the coast is primarily a result of the presence of shallower, more economically developed aquifers such as the Black Creek and Tertiary Limestone (Floridan) Aquifers. Middendorf sediments are comprised of fine to coarse quartzitic and arkosic sands, with discontinuous interbeds of sandy clays, kaolins and gravel. Since the Middendorf Aquifer of the upper Coastal Plain is comprised of clean quartz sands that have been thoroughly leached, only a minimum concentration of ions are present in its water. Groce (1980) described water from the Middendorf Aquifer in the upper Coastal Plain as being generally soft, acidic, and low in dissolved solids, with locally high iron contents. The Middendorf Aquifer wells sampled in the upper Coastal Plain generally conform to this description. In contrast, lower Coastal Plain water from the Middendorf Aquifer is often highly mineralized. The downdip increase in ion concentration is thought to be largely a function of the residence time of the water in the aquifer (flow is from the updip recharge area in the upper Coastal Plain toward downdip, coastal area), as well as from the mixing of more mineralized water from adjacent aquifers.

Two samples from the Middendorf aquifer were obtained during the 2005 sampling event: one from Parris Island along the coast, and one from a public supply well used by the City of Walterboro. The Parris Island sample (AMB-029) displayed a comparatively unique chemistry with elevated conductivity, boron, and fluoride. This combination is typical of some Middendorf wells adjacent to the coast, and is a reflection of the highly mineralized waters found in the deeper formations in the area. AMB-029 also produced detectable levels of tin and lithium. There was technical difficulty with the sodium analysis for this sample, so no value appears in table 1. The sample obtained from the City of Walterboro is sodium-chloride type water with detectable levels of boron (0.24 mg/L). The results from AMB-031 indicate that water from this portion of the Middendorf aquifer is suitable for most uses, though the sodium value is slightly elevated.

Black Creek Aquifer

Though present throughout much of the Coastal Plain, development of the Black Creek aquifer has been conducted primarily in the mid-to-northern portions of the Coastal Plain. The aquifer is composed of silt and fine sand with coarse sand in the Upper Coastal Plain. The Black Creek aquifer is not utilized throughout the Savannah-Salkehatchie basin because of the presences of shallower, more economically developed aquifers. In the upper Coastal Plain water obtained from the Black Creek is very similar to that found in the Middendorf, and the aquifers may in fact be hydraulically connected. Downdip, alkalinity and sodium generally increase, and pH increases as the waters are buffered with calcium carbonate (table 1). The single sample obtained from the Black Creek aquifer was taken from the Town of Bamberg, and is suitable for most uses. With the exception of slightly elevated iron (1.7 mg/L), no objectionable results were obtained for this aquifer at this location.

On a statewide basis, samples obtained from the Black Creek aquifer display high variability in their composition (fig. 6), and samples from the recharge areas through the middle Coastal Plain often show no dominant ionic affinity. With increased distance from the recharge area, Black Creek waters become more buffered and are typically a sodium bicarbonate type. Proximal to the coast, samples from the Black Creek become increasingly sodium chloride-type waters.

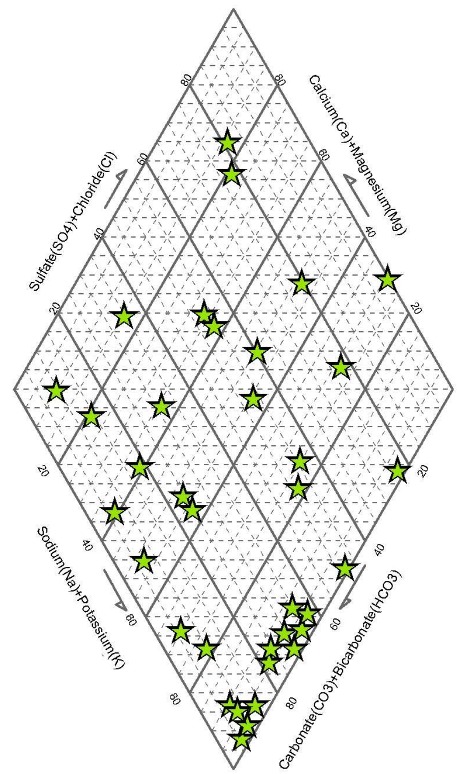

Figure 6: Partial ternary diagram of samples results from the Black Creek aquifer in South Carolina.

Pee Dee Aquifer

Within the Savannah-Salkehatchie basin, the Pee Dee aquifer generally produces water of excellent quality at good-to-moderate rates, though few wells exploit this groundwater source (table 1). Where utilized, the aquifer matrix is composed of coarse sand and silt separated by discontinuous intervals of clay (Logan and Euler, 1989). Development of the Pee Dee aquifer sometimes takes place in conjunction with the more prolific Black Creek aquifer. The Pee Dee aquifer is most utilized in the northeast portion of the State, with the most demand centered between Florence and Horry Counties. AMB-051 at the Allendale Industrial Park is screened in both the Pee Dee and the Black Creek aquifers, and results from the composite sample are very similar to the Black Creek sample obtained from the City of Bamberg (AMB-001). Sampling results from this well indicate that the water is suitable for most uses and none of the analyses indicated objectionable chemistry.

Tertiary Limestone/Sand Aquifer (Floridan Aquifer System)

Within the Savannah-Salkehatchie Basin, the Tertiary Limestone/Sand system is commonly utilized for industrial, agricultural, and public and private water supply. The updip portions of the aquifer system are generally composed of sand and are present near the Fall Line. In this updip area, the aquifer is mainly unconfined and receives most of its recharge directly from rainfall and surface water bodies. In Barnwell and Allendale Counties, the formations that compose the aquifer become increasingly calcareous, with sand content diminishing. The change in aquifer matrix alters the hydraulic properties of the system, and often results in increased yield from wells.

Water from the Tertiary Limestone (Floridan) is generally moderately hard, with pH ranging between 7-8.5, and is generally characterized as calcium-carbonate type water (table 1). The metals content is generally very low, except in some areas near the coast, which may have locally high iron content. Occasionally, elevated sulfur content can cause foul odors and tastes, though this is rare and may also only occur near the coastal areas. Within Hampton, Jasper, and Beaufort Counties, the uppermost portions of the Tertiary Limestone aquifer system is extremely porous and permeable and is commonly referred to as the Upper Floridan aquifer. This aquifer is the primary source of water in the region and is generally of excellent quality, except in areas proximal to sources of saltwater intrusion

The threat of saltwater intrusion has caused a great deal of concern in the Beaufort county area. Due to geologic circumstances, the aquifer is very close to land surface, and is covered by only a thin veneer of confining unit. In addition, nearly a century of heavy groundwater withdrawals in the Savannah –area has reversed groundwater flow and allowed seawater to contaminate freshwater supplies. Typically, the upper Floridan aquifer displays a chloride concentration of less than 6 mg/L (fig. 7), but elevated levels are present in AMB-124, AMB-090, and AMB-095. SCDHEC has monitored salt-water intrusion on northern Hilton Head Island since 1997 and has detected chloride concentrations equaling approximately half that of seawater in some monitoring wells. Saltwater intrusion has affected the water quality in several public supply wells on Hilton Head Island, and has caused them to produce waters that exceed the EPA's 250 mg/L limit for chloride, thus rendering the well unusable. Unless additional reductions in groundwater use in the area occur, the chloride concentrations will only continue to increase.

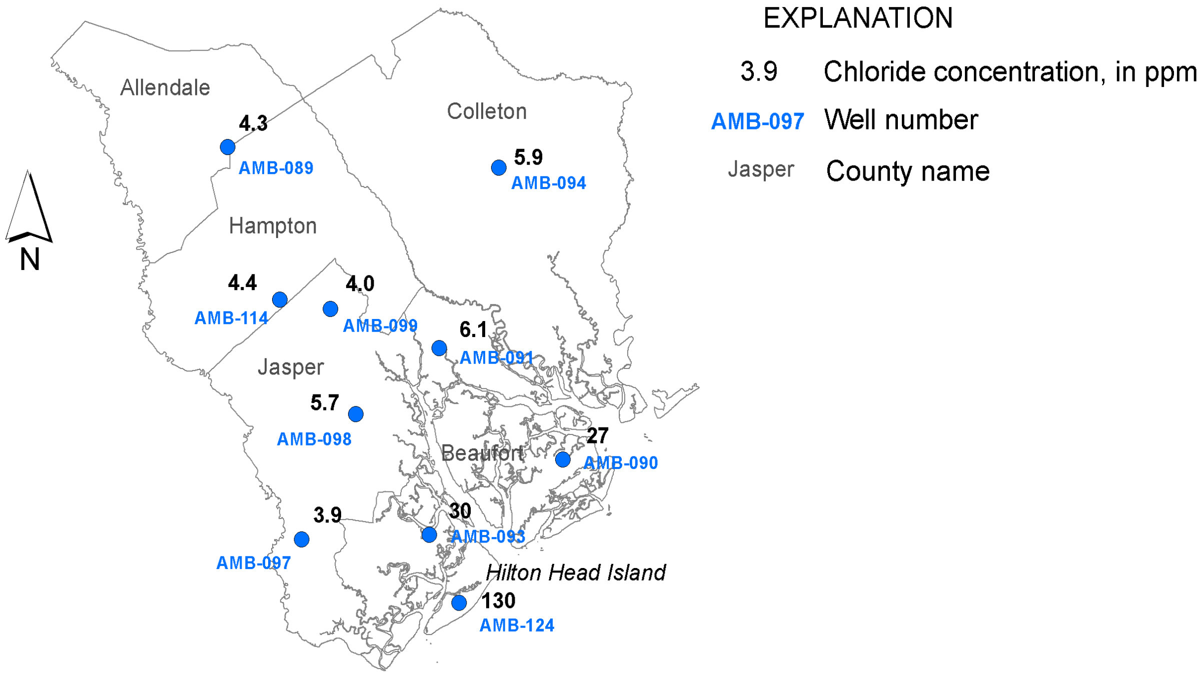

Figure 7: Distribution of chloride in the Tertiary Limestone (Floridan) aquifer

Surficial Aquifer

The Surficial Aquifer is a shallow Coastal Plain aquifer system that is utilized mainly as a source of private water supply for homes and small industry. Water pumped from this aquifer typically has an obvious odor and distinct taste but is still within standards for drinking water, except where it has been influenced by tidal water bodies or contamination. This aquifer is frequently utilized because its shallow nature allows for inexpensive well construction and yields are adequate for domestic use. It should be noted that due to the shallow, unconfined nature of the Surficial aquifer, the system is extremely susceptible to contamination, both natural and man-made. Such sources of contamination include septic tanks, above and underground petroleum storage tanks, brackish water from tidal creeks and wetlands, and other point and non-point sources from roadways, and agricultural and industrial operations.

During the 2005 sampling event water quality from a single well from the Surficial aquifer in Colleton County was analyzed. This well, AMB-086, produced highly objectionable results, with water quality unsuitable for most uses. The well was originally drilled as a possible private supply and irrigation well, but the proximity to a tidal saltwater body has rendered the aquifer unusable in that location (table 1). The results of analyses indicate that AMB-086 produces water high in aluminum (25 ppm), chloride (1,300 ppm), fluoride (2.7 ppm), iron (0.79 ppm), and sulfate (270 ppm). With the exception of the anomalously high aluminum result (which may be caused by corrosion of a metallic pump assembly), similar results should be expected from other wells screened in the Surficial aquifer near the coast.

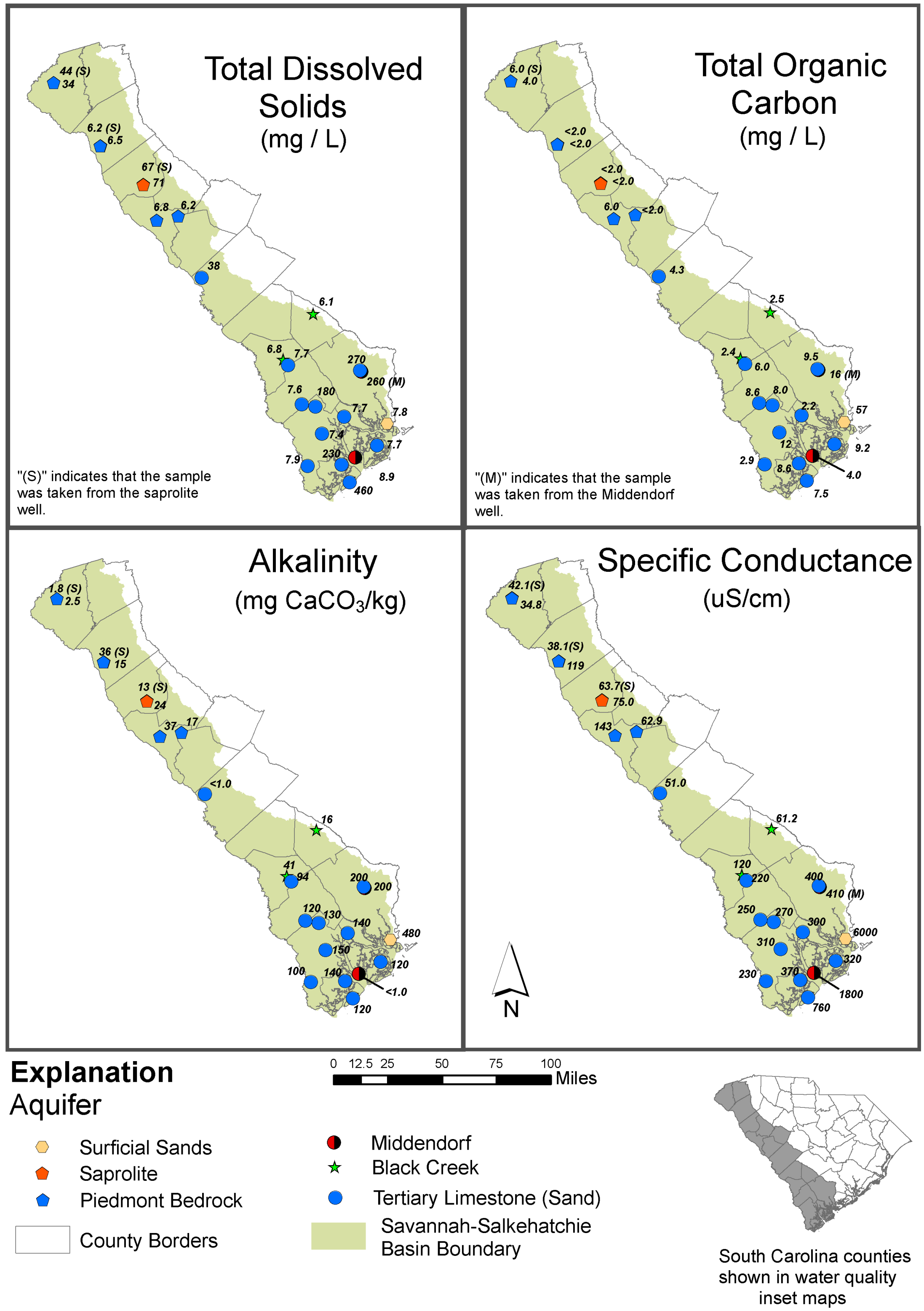

Figure 8: Comparison of selected water quality results from the 2005 Ambient Groundwater Quality Network

Table 1: Water quality analysis results for 2005 ambient groundwater samples.
[Cond, conductivity, TDS, total dissolved solids, Hardness, as mgCaCo3/kg; ppm, parts per million (equivalent to mg/kg or mg/L), field pH measurements are not available for 2005, and SCDHEC does not report laboratory derived pH measurements]

Well	Location	Latitude	Longitude	County	Aquifer	Date
AMB-001	City of Bamberg	33.28	-81.04	Bamberg	Black Creek	4/1/2005
AMB-029	Parris Island	32.32	-80.7	Beaufort	Middendorf	4/1/2005
AMB-031	City of Walterboro	32.9	-80.65	Colleton	Middendorf	4/1/2005
AMB-051	Allendale Industral Park	32.98	-81.27	Allendale	PeeDee\Black Creek	4/1/2005
AMB-054	Abbeville Deep Well	34.14	-82.4	Abbeville	Piedmont Bedrock Well	4/1/2005
AMB-055	Starr Shallow Well	34.39	-82.75	Anderson	Saprolite	4/1/2005
AMB-070	Mountain rest	34.81	-83.14	Oconee	Saprolite	4/1/2005
AMB-075	Abbeville Shallow Well	34.14	-82.4	Abbeville	Saprolite	4/1/2005
AMB-076	Starr Deep Well	34.39	-82.75	Anderson	Piedmont Bedrock	4/1/2005
AMB-081	Mountain Rest	34.81	-83.14	Oconee	Piedmont Bedrock	4/1/2005
AMB-086	Bennets Point-Baily	32.55	-80.45	Colleton	Surf sands	4/1/2005
AMB-089	Town of Fairfax	32.94	-81.23	Allendale	Tertiary Limestone	4/1/2005
AMB-090	Frogmore	32.4	-80.53	Beaufort	Tertiary Limestone	4/1/2005
AMB-091	Sheldon	32.59	-80.79	Beaufort	Tertiary Limestone	4/1/2005
AMB-093	Bluffton	32.27	-80.81	Beaufort	Tertiary Limestone	4/1/2005
AMB-094	City of Walterboro 29	32.9	-80.66	Colleton	Tertiary Limestone	4/1/2005
AMB-097	Town of Hardeeville	32.27	-81.08	Jasper	Tertiary Limestone	4/1/2005
AMB-098	Town of Ridgeland	32.48	-80.96	Jasper	Tertiary Limestone	4/1/2005
AMB-099	Town of Grays	32.66	-81.02	Jasper	Tertiary Limestone	4/1/2005
AMB-107	Fairview Forest Manor	33.93	-82.12	Edgefield	Piedmont Bedrock	4/1/2005
AMB-114	WSHB Radio	32.68	-81.12	Hampton	Tertiary Limestone	4/1/2005
AMB-115	McCormick CPW	34.75	-80.41	McCormick	Piedmont Bedrock	4/1/2005
AMB-123	N. August Breezy Hill	33.52	-81.922	Aiken	Tertiary Sands	4/1/2005
AMB-124	Hilton Head Wexford	32.16	-80.75	Beaufort	Tertiary Limestone	4/1/2005

Table 1, continued: Water quality analysis results for 2005 ambient groundwater samples.
[Cond, conductivity µS/cm, TDS, total dissolved solids, Hardness, as mg $CaCO_3$/kg; ppm, parts per million (equivalent to mg/kg or mg/L), field pH measurements are not available for 2005, and SCDHEC does not report laboratory derived pH measurements]

Well	Location	pH	Cond	Alk	TDS	Hardness
AMB-001	City of Bamberg	--	61.2	16	6.1	11
AMB-029	Parris Island	--	1800	<1.0	8.9	1.8
AMB-031	City of Walterboro	--	400	200	270	10
AMB-051	Allendale Industral Park	--	120	41	6.8	26
AMB-054	Abbeville Deep Well	--	75	24	71	20
AMB-055	Starr Shallow Well	--	38.1	15	6.2	12
AMB-070	Mountain Rest	--	42.1	1.8	44	7.7
AMB-075	Abbeville Shallow Well	--	63.7	13	67	15
AMB-076	Starr Deep Well	--	119	36	6.5	44
AMB-081	Mountain Rest	--	34.8	2.5	34	5.8
AMB-086	Bennets Point-Baily	--	6000	480	7.8	140
AMB-089	Town of Fairfax	--	220	94	7.7	52
AMB-090	Frogmore	--	320	120	7.7	110
AMB-091	Sheldon	--	300	140	7.7	100
AMB-093	Bluffton	--	370	140	230	150
AMB-094	City of Walterboro 29	--	410	200	260	11
AMB-097	Town of Hardeeville	--	230	100	7.9	80
AMB-098	Town of Ridgeland	--	310	150	7.4	130
AMB-099	Town of Grays	--	270	130	180	120
AMB-107	Fairview Forest Manor	--	62.9	17	6.2	6.5
AMB-114	WSHB Radio	--	250	120	7.6	110
AMB-115	McCormick CPW	--	143	37	6.8	34
AMB-123	N. August Breezy Hill	--	51	<1.0	38	5.5
AMB-124	Hilton Head Wexford	--	760	120	460	160

Table 1, continued: Water quality analysis results for 2005 ambient groundwater samples.

Well	Location	Ag, ppm	Al, ppm	As, ppm	B, ppm	Ba, ppm	Be, ppm	Ca, ppm	Cd, ppm	Cl, ppm
AMB-001	City of Bamberg	<0.030	<0.10	<0.0050	<0.10	0.08	<0.0030	3.5	<0.010	1.9
AMB-029	Parris Island	<0.030	<0.10	<0.0050	4.2	<0.050	<0.0030	0.49	<0.010	34
AMB-031	City of Walterboro	<0.030	<0.10	<0.0020	0.24	<0.050	<0.0030	2.6	<0.010	4
AMB-051	Allendale Industral Park	<0.030	<0.10	<0.0020	<0.10	0.067	<0.0030	8.5	<0.010	4.2
AMB-054	Abbeville Deep Well	<0.030	<0.10	<0.0020	<0.10	<0.050	<0.0030	6.2	<0.010	2.8
AMB-055	Starr Shallow Well	<0.030	<0.10	<0.0020	<0.10	<0.050	<0.0030	2.7	<0.010	2
AMB-070	Mountain Rest	<0.030	0.4	<0.0050	<0.10	<0.050	0.0064	2.1	<0.010	3
AMB-075	Abbeville Shallow Well	<0.030	<0.10	<0.0020	<0.10	0.064	<0.0030	5.2	<0.010	2.5
AMB-076	Starr Deep Well	<0.030	<0.030	<0.0020	<0.10	<0.050	0.0048	10	<0.010	4.5
AMB-081	Mountain Rest	<0.030	0.11	<0.0020	<0.10	<0.050	0.0049	1.1	<0.010	2.4
AMB-086	Bennets Point-Baily	<0.030	25	0.0022	3.1	<0.050	<0.0030	18	<0.010	1300
AMB-089	Town of Fairfax	<0.030	<0.10	<0.0020	<0.10	<0.050	<0.0030	14	<0.010	4.3
AMB-090	Frogmore	<0.030	<0.10	<0.0050	<0.10	<0.050	<0.0030	37	<0.010	27
AMB-091	Sheldon	<0.030	<0.10	<0.0020	<0.10	<0.050	<0.0030	24	<0.010	6.1
AMB-093	Bluffton	<0.030	<0.10	<0.0020	<0.10	<0.050	<0.0030	37	<0.010	30
AMB-094	City of Walterboro 29	<0.030	<0.10	<0.0050	0.2	<0.050	<0.0030	2.6	<0.010	5.9
AMB-097	Town of Hardeeville	<0.030	<0.10	<0.0050	<0.10	<0.050	<0.0030	18	<0.010	3.9
AMB-098	Town of Ridgeland	<0.030	<0.10	<0.0050	<0.10	<0.050	<0.0030	43	<0.010	5.7
AMB-099	Town of Grays	<0.030	<0.10	<0.0020	<0.10	<0.050	<0.0030	41	<0.010	4
AMB-107	Fairview Forest Manor	<0.030	<0.10	<0.0020	<0.10	<0.050	<0.0030	2.3	<0.010	3.8
AMB-114	WSHB Radio	<0.030	<0.10	<0.0020	<0.10	<0.050	<0.0030	40	<0.010	4.4
AMB-115	McCormick CPW	<0.030	<0.10	<0.0050	<0.10	<0.050	<0.0030	10	<0.010	6.7
AMB-123	N. August Breezy Hill	<0.030	<0.10	<0.0050	<0.10	<0.050	<0.0030	1.2	<0.010	4.7
AMB-124	Hilton Head Wexford	<0.030	<0.10	<0.0050	0.13	<0.050	<0.0030	36	<0.010	130

Well	Location	Co, ppm	Cr, ppm	Cu, ppm	F, ppm	Fe, ppm	Hg, ppm	K, ppm	Li, ppm	Mg, ppm
AMB-001	City of Bamberg	<0.020	<0.010	<0.010	<0.10	1.7	<0.00020	6.4	0.028	0.55
AMB-029	Parris Island	<0.020	<0.010	<0.010	4.8	0.082	<0.00020	4	0.023	0.15
AMB-031	City of Walterboro	<0.020	<0.010	<0.010	0.9	0.07	<0.00020	7.8	<0.010	0.96
AMB-051	Allendale Industral Park	<0.020	<0.010	<0.010	0.2	0.58	<0.00020	5.4	<0.010	1.1
AMB-054	Abbeville Deep Well	<0.020	<0.010	<0.010	0.11	<0.020	<0.00020	1.6	<0.010	0.98
AMB-055	Starr Shallow Well	<0.020	<0.010	<0.010	<0.10	0.099	<0.00020	1	<0.010	1.3
AMB-070	Mountain Rest	<0.020	<0.010	0.037	<0.10	0.2	<0.00020	1.6	<0.010	0.59
AMB-075	Abbeville Shallow Well	<0.020	<0.010	0.03	0.045	<0.020	<0.00020	2.6	<0.010	0.58
AMB-076	Starr Deep Well	<0.020	0.01	<0.010	<0.10	<0.020	<0.00020	1.4	<0.010	4.6
AMB-081	Mountain Rest	<0.020	<0.010	0.011	<0.10	<0.020	<0.00020	1.2	<0.010	0.75
AMB-086	Bennets Point-Baily	<0.020	<0.010	0.013	2.7	0.79	<0.00020	40	0.041	24
AMB-089	Town of Fairfax	<0.020	<0.010	<0.010	0.33	<0.020	<0.00020	6.7	<0.010	4.2
AMB-090	Frogmore	<0.020	<0.010	<0.010	0.27	<0.020	<0.00020	4.1	<0.010	5
AMB-091	Sheldon	<0.020	<0.010	<0.010	0.28	<0.020	<0.00020	8.1	<0.010	10
AMB-093	Bluffton	<0.020	<0.010	<0.010	0.32	<0.020	<0.00020	2.5	<0.010	13
AMB-094	City of Walterboro 29	<0.020	<0.010	<0.010	0.93	<0.020	<0.00020	9	<0.010	1.2
AMB-097	Town of Hardeeville	<0.020	<0.010	<0.010	0.4	0.13	<0.00020	2.8	<0.010	8.4
AMB-098	Town of Ridgeland	<0.020	<0.010	<0.010	0.21	<0.020	<0.00020	2.6	<0.010	6.4
AMB-099	Town of Grays	<0.020	<0.010	<0.010	0.18	<0.020	<0.00020	1.6	<0.010	4.2
AMB-107	Fairview Forest Manor	<0.020	<0.010	0.026	2	0.04	<0.00020	1.3	<0.010	0.19
AMB-114	WSHB Radio	<0.020	<0.010	<0.010	0.15	<0.020	<0.00020	1.2	<0.010	2.8
AMB-115	McCormick CPW	<0.020	<0.010	<0.010	0.83	0.19	<0.00020	1.9	<0.010	2.2
AMB-123	N. August Breezy Hill	<0.020	<0.010	0.016	<0.10	0.029	<0.00020	<1.0	<0.010	0.62
AMB-124	Hilton Head Wexford	<0.020	<0.010	<0.010	0.43	0.14	<0.00020	4.7	0.01	17

Table 1, continued: Water quality analysis results for 2005 ambient groundwater samples.

Well	Location	Mn, ppm	Mo, ppm	Na, ppm	Ni, ppm	NO3, ppm	Pb, ppm	Sb, ppm	Si, ppm	Sn, ppm
AMB-001	City of Bamberg	0.032	<0.020	1.9	<0.020	<0.020	<0.050	<0.050	16	<0.020
AMB-029	Parris Island	<0.010	<0.020	--	<0.020	<0.020	<0.050	<0.050	7.5	0.047
AMB-031	City of Walterboro	<0.010	<0.020	95	<0.020	<0.020	<0.050	<0.050	38	<0.020
AMB-051	Allendale Industral Park	0.014	<0.020	12	<0.020	<0.020	<0.050	<0.050	13	<0.020
AMB-054	Abbeville Deep Well	<0.010	<0.020	5.6	<0.020	1.6	<0.050	<0.050	21	<0.020
AMB-055	Starr Shallow Well	<0.010	<0.020	1.7	<0.020	0.52	<0.050	<0.050	15	<0.020
AMB-070	Mountain Rest	0.085	<0.020	2.5	<0.020	2	<0.050	<0.050	7	<0.020
AMB-075	Abbeville Shallow Well	<0.010	<0.020	3.8	<0.020	2.6	<0.050	<0.050	17	<0.020
AMB-076	Starr Deep Well	<0.010	<0.020	3.6	<0.020	3.9	<0.050	<0.050	26	<0.020
AMB-081	Mountain Rest	0.076	<0.020	2.3	<0.020	1.7	<0.050	<0.050	8.5	<0.020
AMB-086	Bennets Point-Baily	0.01	<0.020	1100	<0.020	0.031	<0.050	<0.050	33	0.046
AMB-089	Town of Fairfax	<0.010	<0.020	23	<0.020	<0.020	<0.050	<0.050	27	<0.020
AMB-090	Frogmore	<0.010	<0.020	19	<0.020	<0.020	<0.050	<0.050	23	<0.020
AMB-091	Sheldon	<0.010	<0.020	20	<0.020	<0.020	<0.050	<0.050	31	<0.020
AMB-093	Bluffton	0.016	<0.020	19	<0.020	<0.020	<0.050	<0.050	31	<0.020
AMB-094	City of Walterboro 29	<0.010	<0.020	95	<0.020	<0.020	<0.050	<0.050	28	<0.020
AMB-097	Town of Hardeeville	<0.010	<0.020	16	<0.020	<0.020	<0.050	<0.050	40	<0.020
AMB-098	Town of Ridgeland	0.059	<0.020	11	<0.020	<0.020	<0.050	<0.050	34	<0.020
AMB-099	Town of Grays	0.035	<0.020	8.7	<0.020	<0.020	<0.050	<0.050	20	<0.020
AMB-107	Fairview Forest Manor	<0.010	<0.020	9.1	<0.020	0.38	<0.050	<0.050	60	<0.020
AMB-114	WSHB Radio	0.018	<0.020	8.4	<0.020	<0.020	<0.050	<0.050	27	<0.020
AMB-115	McCormick CPW	<0.010	<0.020	13	<0.020	0.054	<0.050	<0.050	13	<0.020
AMB-123	N. August Breezy Hill	<0.010	<0.020	5.4	<0.020	3	<0.050	<0.050	7.3	<0.020
AMB-124	Hilton Head Wexford	0.017	<0.020	92	<0.020	<0.020	<0.050	<0.050	38	<0.020

Well	Location	SO4, ppm	Sr, ppm	TNK, ppm	U, ppm
AMB-001	City of Bamberg	5.9	0.03	0.12	<0.15
AMB-029	Parris Island	8.3	0.036	0.79	<0.15
AMB-031	City of Walterboro	<5.0	0.047	0.22	<0.15
AMB-051	Allendale Industral Park	<5.0	0.064	0.12	<0.15
AMB-054	Abbeville Deep Well	<5.0	0.025	0.48	<0.15
AMB-055	Starr Shallow Well	<5.0	0.015	0.19	<0.15
AMB-070	Mountain rest	<5.0	0.014	0.28	<0.15
AMB-075	Abbeville Shallow Well	<5.0	0.062	0.28	<0.15
AMB-076	Starr Deep Well	<5.0	0.046	0.14	<0.15
AMB-081	Mountain Rest	<5.0	0.013	0.2	<0.15
AMB-086	Bennets Point-Baily	270	0.6	1.5	<0.15
AMB-089	Town of Fairfax	19	0.15	0.16	<0.15
AMB-090	Frogmore	22	0.24	0.42	<0.15
AMB-091	Sheldon	<5.0	0.48	0.44	<0.15
AMB-093	Bluffton	<5.0	0.77	0.36	<0.15
AMB-094	City of Walterboro 29	<5.0	0.053	0.2	<0.15
AMB-097	Town of Hardeeville	<5.0	0.5	0.36	<0.15
AMB-098	Town of Ridgeland	<5.0	0.33	0.11	<0.15
AMB-099	Town of Grays	<5.0	0.18	0.3	<0.15
AMB-107	Fairview Forest Manor	<5.0	<0.010	0.15	<0.15
AMB-114	WSHB Radio	6	0.19	0.19	<0.15
AMB-115	McCormick CPW	<5.0	0.068	0.18	0.15
AMB-123	N. August Breezy Hill	11	<0.010	0.27	<0.15
AMB-124	Hilton Head Wexford	<5.0	0.75	0.41	<0.15

Aquifer Vulnerability

The vulnerability of an aquifer to man-made contaminants depends on the degree of confinement and isolation from the land surface afforded to groundwater in a particular geologic setting. Groundwater found in the metamorphic and igneous rocks of the Piedmont is generally unconfined during major portions of its flow path, and therefore, is susceptible to surface contamination. In some cases, water moving through fractures may be isolated from both the atmosphere and near-surface contaminants for considerable amounts of time, but inevitably, that water will eventually mix with "newer" water introduced into the flow regime as recharge from rainfall or streams.

Studies conducted by SCDHEC, in cooperation with the South Carolina Department of Natural Resources (SCDNR) have discovered that many springs and wells in the Savannah-Salkehatchie Basin, as well as other parts of the Piedmont and Blue Ridge provinces, contain chemicals that are only present in the modern (<60 years) atmosphere, such as tritium (^3H). Tritium has been detected globally at low concentrations in all surface waters since the initiation of nuclear weapons testing in the 1950s (Stone and others, 1989, Stone and others, 2005). The presence of tritium in groundwater, while not necessarily an indicator of contamination, positively indicates whether or not pathways of contamination are present within a groundwater flow system. Based on the presence of tritium from many wells in the Piedmont, all of the Savannah-Salkehatchie Basin above the Fall Line should be considered vulnerable to contamination. Users of private wells in the Piedmont are encouraged to have routine testing done on their drinking water supplies.

In the upper and middle Coastal Plain, sand and limestone aquifers are also vulnerable to surface contamination because they lack an effective confining unit. In the eastern half of Hampton county, and the majority of Jasper and Beaufort Counties, the principal aquifer is well confined and there is little chance for surface contamination entering the groundwater supply. Areas near Beaufort, Saint Helena Island, and Hilton Head Island are an exception and are vulnerable to surface contamination because the confining unit is quite thin in these areas. Elevated chloride concentrations in the aquifer from saltwater intrusion are a testament to the vulnerability of the groundwater supply in these areas.

Naturally Occurring Radionuclides

In portions of the Savannah-Salkehatchie Basin, naturally occurring radionuclides have been detected in some private and public water supplies. Elevated levels of radium, radon, and uranium have been detected in the Piedmont region of the basin, though in no distinct pattern. During the 2005 monitoring event, well AMB-115 at McCormick returned a uranium concentration of 0.15 ppm, half of the current MCL (maximum concentration limit). Such values are not uncommon in the Piedmont region.

Recent DHEC studies have identified several areas in Aiken County that naturally occurring radionuclides in groundwater. In addition to the mandated sampling performed by all public water supplies, additional sampling and studies are being conducted in the area to understand the distribution and occurrence of these radionuclides.

Summary

An ambient groundwater quality monitoring network for South Carolina's major aquifers has been outlined and established throughout the State. Network organization includes the consideration of factors such as well selection, sampling intervals and methods, chemical analysis, data management, a network implementation schedule and estimates of overall expenses. The data generated from the groundwater monitoring network provides both a baseline of information to be used in future groundwater investigations, and a better understanding of the chemical nature of one of South Carolina's most essential resources.

Acknowledgements

Thanks are due to Rob Devlin for management of the water quality data through the STORET database, and Pete Stone for information on aquifer vulnerability and naturally occurring radionuclides. The cooperation of municipal and private well owners was also a critical factor and is well appreciated. This report has been funded by the U.S. Environmental Protection Agency, Region IV, through Section 106 of the Clean Water Act.

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Appendix A: Ambient Monitoring Network Groundwater Quality Parameters

nitrate + nitrite
hardness
chloride
sulfate
TDS (Total Dissolved Solids)
pH
alkalinity
fluoride
TOC (Total Organic Carbon)
specific conductivity
aluminum
beryllium
boron
cobalt
strontium
mercury
molybdenum
TKN (Total Kjehldahl Nitrogen)
silica
zinc
calcium
magnesium
sodium
potassium
arsenic
barium
copper
iron
lead
manganese
selenium
silver
tin
uranium
cadmium
chromium
nickel
antimony
lithium

Appendix B: Maximum Contaminant Levels

The maximum contaminant levels for inorganic chemicals are as follows:

Contaminant	Level (mg/l)
Antimony	0.006
Arsenic	0.05
Barium	2.0
Beryllium	0.004
Cadium	0.005
Chromium	0.10
Fluoride	4.0
Lead	0.015
Mercury	0.002
Nickel	0.1
Nitrate (as N)	10.0
Nitrite (as N)	1.0
Selenium	0.05

Secondary Maximum Contaminant Levels

The secondary maximum contaminant levels are applicable to both community and non-community water systems. The secondary maximum contaminant levels are as follows:

Contaminant	Level
Aluminum	0.05 to .2 mg/l
Chloride	250 mg/l
Color	15 color units
Copper	1 mg/l
Corresivity	Noncorrosive
Fluoride	2.0 mg/l
Foaming Agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 threshold odor #
pH	6.5-8.5
Silver	0.10 mg/l
Sulfate	250 mg/l
Total Dissolved Solids (TDS)	500 mg/l
Zinc	5 mg/l

Source: National Primary Drinking Water Regulations – EPA's Drinking Water Standards: http://www.epa.gov/safewater/mcl.html